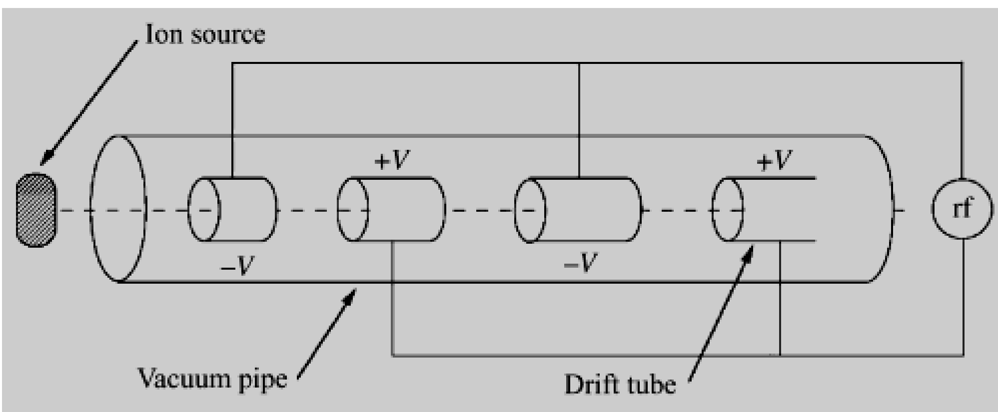
Resonance Accelerators

Multiple-stage linear accelerator (Linac or Linear Accelerator)

Linear accelerators, as the name implies, accelerate particles along linear trajectories rather than in circular orbits. These accelerators are also based on the resonance principle, and operate as follows. A series of metal tubes, called drift tubes, are located in a vacuum vessel and connected successively to alternate terminals of a radio frequency oscillator, as shown in next figure. Let us suppose that at some time the fields are as shown in the figure. Positive ions from the source will then be accelerated by the electric field towards the first drift tube. If the alternator can change its direction before the ions pass through that tube, then they will be accelerated again on their way between the exit of the first and entry into the second tube, and so on. However, as the particles accelerate, their velocities increase, and consequently, if the drift tubes are all of the same length, the phase between the particle positions and the potentials at the next tube may not keep in step (that is, the next gap may not accelerate). To avoid this, the drift tubes are made longer along the path so that one radio-frequency (RF) alternator can accelerate the particles all the way to the end.



Acceleration in a linear ion accelerator

Because electrons become relativistic at relatively low energies, electron linear accelerators act on a slight variation of the principle just described. The electron source is usually a hot wire filament which, effectively, boils off electrons. These are accelerated through a positive potential grid and rapidly become relativistic. Bunches of these electrons are then passed through accelerating tubes that are fed with microwave power delivered by klystron amplifiers. Electrons radiate easily as they get accelerated, and therefore much power is needed to increase their energy. This power is supplied by the microwave fields that travel in step with electrons in specially shaped iris-loaded waveguides. The longest linear

accelerator is the two-mile Stanford Linac (SLAC), and it accelerates electrons to energies of 50 GeV. It is over 3km long.

An ingenious way of reducing the enormous lengths of high-energy linacs has been developed at the Continuous Electron Beam Accelerator Facility (CEBAF) at the Jefferson Laboratory in the USA. This utilizes the fact that above about 50MeV, electron velocities are very close to the speed of light and thus electrons of very different energies can be accelerated in the same drift tube. Instead of a single long linac, the CEBAF machine consists of two much shorter linacs and the beam from one is bent and passed through the other. This can be repeated for up to four cycles. Even with the radiation losses inherent in bending the beams, very intense beams can be produced with energies between 0.5 and 6.0 GeV. CEBAF is proving to be an important machine in the energy region where nuclear physics and particle physics descriptions overlap.